1961

Habituation of the startle response to tones of varying intensity

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HABITUATION OF THE STARTLE RESPONSE
TO TONES OF VARYING INTENSITY

by

Herman Lowe

A THESIS

Presented to the Graduate Faculty

of Lehigh University

in Candidacy for the Degree of

Master of Science

Lehigh University

1961

This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science in Psychology.

May 20, 1961
(Date)

May 23, 61

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ACKNOWLEDGEMENTS

The author gratefully acknowledges his appreciation to Dr. Solomon Weinstock for his guidance in the formulation of this thesis. His depth of scientific knowledge and devotion as a teacher made this research project an invaluable part of the writer's psychological training.

The writer is also indebted to Dr. Nathan Gross for his help in carrying out the pilot study, Robert Cunitz for his expert technical assistance, and the writer's loving wife, Joyce, for her whole-hearted willingness to assist in the laborious computational and clerical tasks.

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INTRODUCTION

In the present experiment we investigated habituatory response decrement to pure tones as a function of stimulus intensity. Habituatory response is the decrease in the magnitude of an unlearned response due to repeated stimulation. It differs from other forms of response decrement occurring as a result of receptor adaptation, loss of effector ability to respond, or any of the various types of inhibition. In habituatory response phenomena trial spacing is sufficiently large to rule out the above possibilities. The amount of habituation has been shown to vary with strength of stimulus, sense modality, response, and with species (Harris, 1943). However, most of the studies done have used frequency, rather than amplitude, of response and little is known about the trial by trial changes in response magnitude. It is the purpose of the present study to explore the detailed quantitative changes in response amplitude as a function of three levels of auditory stimulation.

Several investigators have obtained negatively accelerated habituation functions. Coombs (1938) investigated habituation of the Galvanic Skin Reflex as a function of interstimulus-interval. The stimuli used were a variety of loud sounds and "pure" tones. For all stimuli the habituation curve was negatively accelerated.

Davis (1934) investigated habituation of the G.S.R. to a 1000 c.p.s. tone. He found negatively accelerated decrements from trial to trial and from day to day.

Oldfield (1937) found that the rapidity of habituation of the eyelid reflex to sound depended upon the intensity of the stimulus. Complete habituation in one or two trials was obtained with a click just above threshold, while a painfully loud click led to some habituation followed by oscillation of the response magnitude.

Lehner (1941) found that the number of auditory stimulus presentations necessary to habituate the respiratory startle of the rat decreases with successive habituations. The curve of habituation took the form of a decay function.

Lehner also investigated the habituation of the tail reflex in rats and found a decay function for the number of responses in successive habituations. He recorded the amplitude of the tail reflex and obtained what appear to be decay functions within each of the successive habituations. Unfortunately Lehner plotted the average response magnitude of the Ss who did respond rather than the average across all Ss. In addition each S was run to a criterion of three successive failures to respond, so that the group curve is not based on all Ss. In view of this and the absence of detailed curve fitting, the Lehner data cannot be regarded as providing definitive evidence on the nature of the habituation curve for response amplitude.

Landis and Hunt (1939) using photographic equipment to record the startle response found that all components of the startle reflex except the lid reflex and slight head movements dropped out, though with great variability among individuals.

In the past two decades the development of electromyography has provided a more precise method for studying the startle pattern. Jones and Kennedy (1951) conducted an exploratory study of recording the startle pattern by multiple-channel electromyography and concluded that it is a promising method for studying the startle pattern.

Of all the studies on habituation of various components of the startle response only Lehner (1941) provides evidence that the magnitude of the response is a decay function of the number of stimulus presentations. Much of the other data is consistent with the decay function in that a negatively accelerated function is obtained. One of the purposes of the present study is to determine whether a decay function does provide a good fit to the data. The decay function is chosen here as the theoretical function on the assumption that habituation of an unlearned response follows the same course as extinction of a learned response. The latter curve is typically a decay function.

It is well known from a variety of observations that the initial level of the startle response is a function of intensity of the auditory stimuli used. The present study seeks also to determine whether the terminal levels and the rates of habituation differ as a function of stimulus intensity. Use of electromyographic recording should not only provide a detailed quantitative picture of the course of habituation but also allow us to answer the above questions.

METHOD

Subjects. Forty-five Lehigh University undergraduates enrolled in the Introductory Psychology course, served on a volunteer basis.

Apparatus. Pure tones were produced by an oscillator (General Radio 1304B) and a timer-controlled electronic switch (Grason-Stadler E329A and 829S56). The tone duration was 0.2 sec. with a rise-fall time of 0.1 msec. The signal was passed through an attenuator (Hewlett - Packard 350A) and an impedance matching transformer to Permuflux earphones (PD8-8).

E.M.G. recordings between two monopolar electrodes were amplified and recorded on a Grass Ink-writing Electromyograph. One pen recorded electrical potentials while another was connected to the electronic switch which automatically deflected the pen when a hand switch was closed to put on the tone. Measurements were taken of the time for the tone to reach the S and of the time from beginning of a response to the appearance of a deflection of the pen. The appropriate distance (or time) was then added to the point at which the electronic switch pen deflected to determine the point of onset of the response to tone.

Approximate integrated muscle potentials were obtained by reading the amplitude of deflection of the E.M.G. pen at five equally spaced points in a 0.2 sec. interval before and after onset of the tone. Since the time interval used was always 0.2 sec. the average of the five readings was approximately equal to the integrated muscle potential.

Procedure. Three intensities, 80, 86, and 92 dbs. above threshold, of a 2,000 cps tone, 0.2 sec. in duration, were used. Fifteen Ss were assigned randomly to each of three experimental groups which received the 80,86 and 92 db. stimuli, respectively. Each S received 21 trials on each of which the tone alone was presented. Random intertrial intervals, ranging from 35 to 55 sec. with an average of 45 sec., were used.

Each S had two active electrodes attached to his forehead and one ground electrode attached to his ear. The S was placed on a bed in a sound-proofed chamber and read the following instructions:

"Before we begin the experiment I want to assure you that you will not be given any shocks during the experiment . Your job will be to lie on this bed, to keep your eyes closed, to stay awake, and not to move. What we are doing is measuring brain waves and the changes these waves undergo when you hear a tone. The apparatus we use measures all sorts of movement so you see that it is important that you relax and remain just as still as you possibly can. In fact, in order to help you relax you will be allowed to rest for a short period of time before you will hear any tones. You will be in this room for approximately twenty minutes. Remember to keep your eyes closed, to stay awake, and not to move. Do you understand what you are to do? (The E answered questions only by repeating the relevant part of the instructions). After we are finished I will be glad to answer any questions you have. Are you ready?"

There was a five min. period of rest for each S before the onset of the first tone.

RESULTS

The response measure used throughout this experiment was the difference in integrated muscle potential (I.M.P.) in the 0.2 sec. intervals before and after onset of the tone.

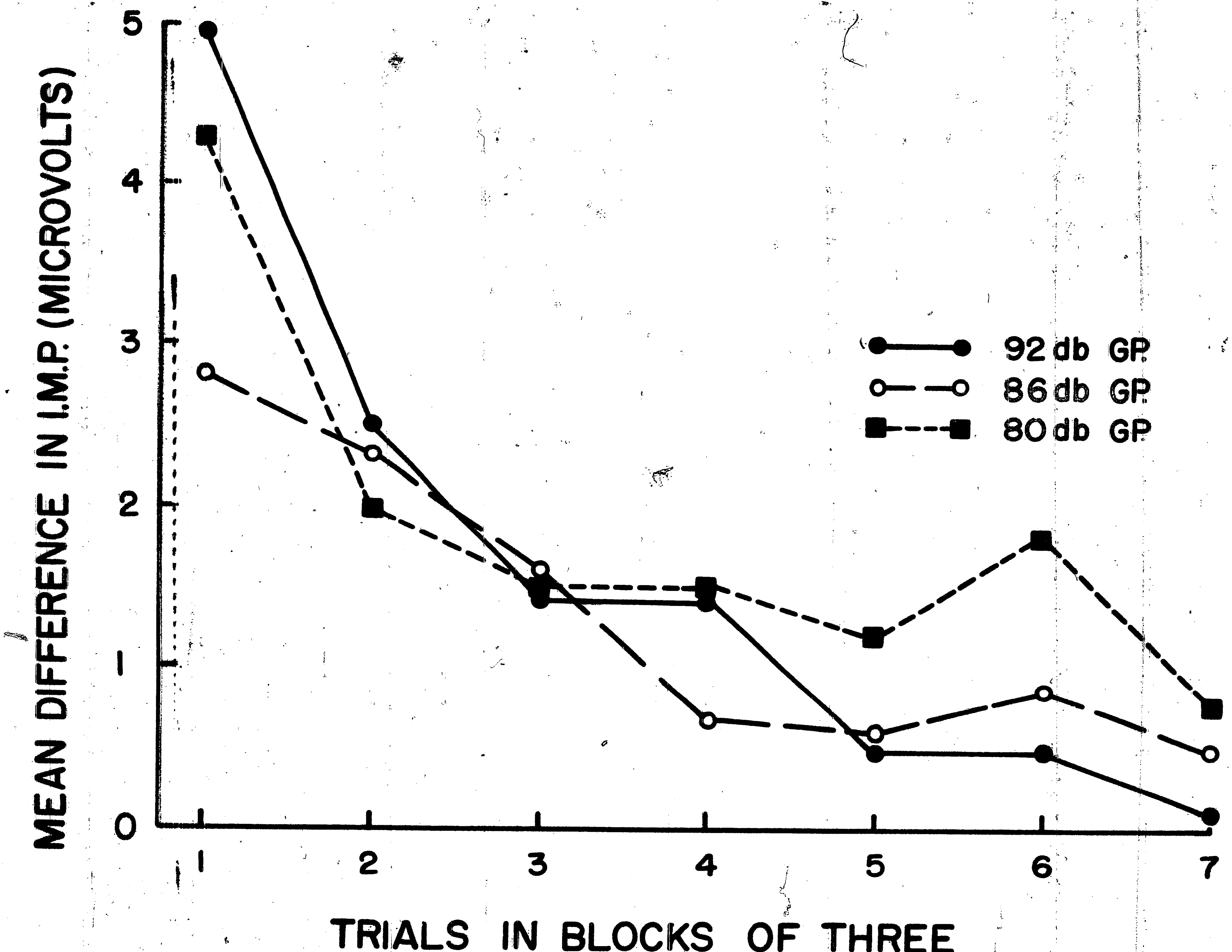
Figure 1 shows mean response in microvolts plotted against trials in blocks of three for each condition. It may be seen that the habituation curves were negatively accelerated. On the first trial block the 80 db group shows a larger response than the 86 db group. It may also be seen that the 92 db condition, which shows the highest initial level, shows the lowest terminal level of response.

The variances for each trial for each of the groups were computed and a scatter plot of means and variances was made. This was done to see whether the variances were homogeneous across trials. In each group the variances increased with increasing means. This suggested a transformation to a log score to achieve homogeneity of variance. Before logs could be taken a constant (eleven) was added to make each score positive. A scatter plot of means and variances was made and showed that as the means increased the variances remained relatively stable. As may be seen from Figure 2, the transformation to common logs allowed the data to be fitted by a straight line.

An analysis of variance was performed on the average transformed scores for the first trial block and the results are presented in Table 1. The results of the *F* test between groups showed no significant differences at the 5% level.

An analysis of variance was performed on the average transformed scores for the last two blocks of trials and the results appear in Table 2. The *F* between groups was not significant at the 5% level.

Figure 1: Mean difference in I.M.P. (microvolts) as a function of trials in blocks of three.



MEAN DIFFERENCE IN I.M.P. (MICROVOLTS)
5
4
3
2
1
0
1
2
3
4
5
6
7
TRIALS IN BLOCKS OF THREE
92 db GP
86 db GP
80 db GP

Figure 2: Mean of the transformed response measure (log of I.M.P. & 11) as a function of trials in blocks of three.

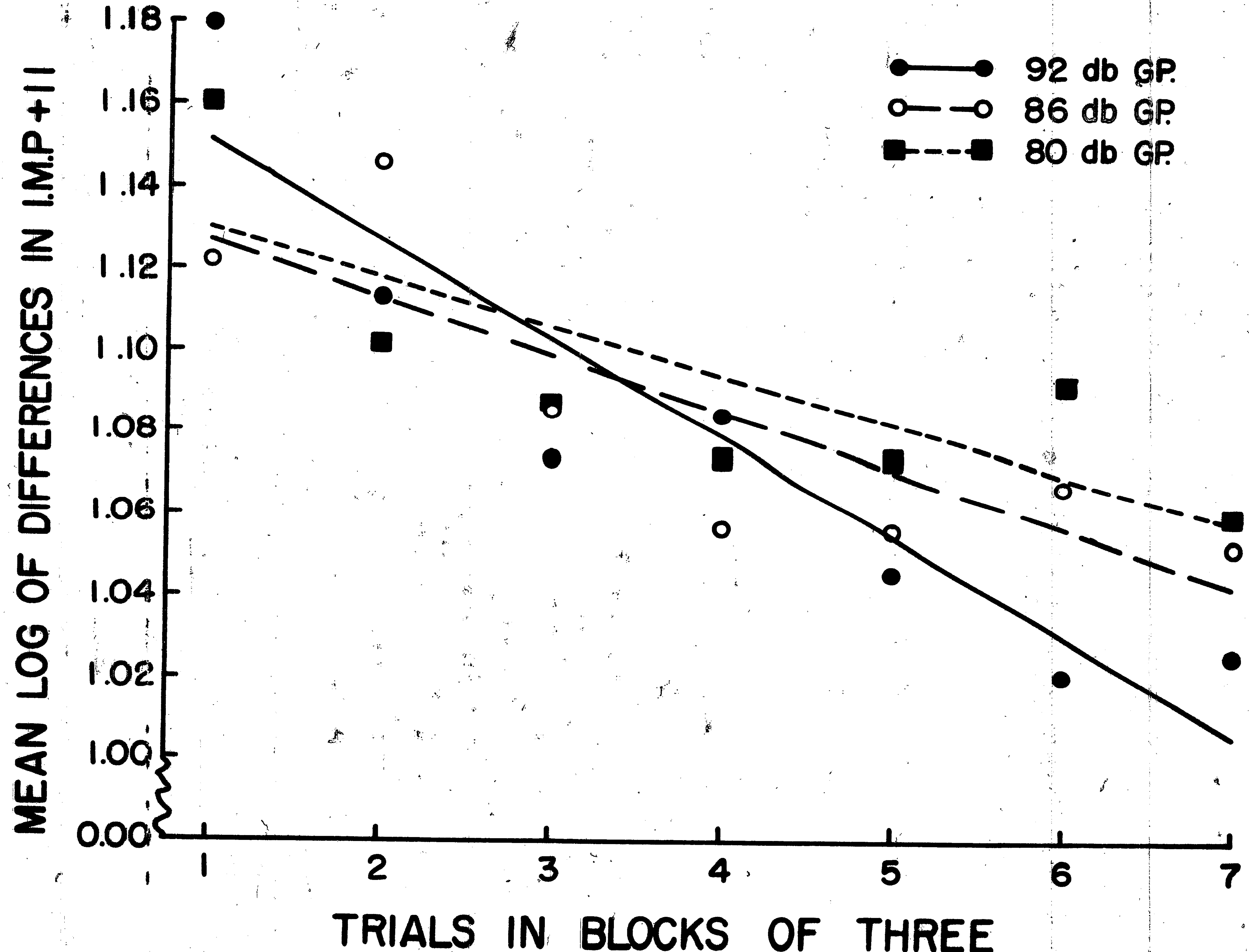

92 db GP.
86 db GP.
80 db GP.
MEAN LOG OF DIFFERENCES IN I.M.P.+11
1.18
1.16
1.14
1.12
1.10
1.08
1.06
1.04
1.02
1.00
0.00
1
2
3
4
5
6
7
TRIALS IN BLOCKS OF THREE

Table 1

Summary of Analysis of Variance for Initial Level of Responding

Source	Sum of Squares	df	Mean Square	F
Between Groups	.0262	2	.0131	1.16 n.s.
Within Groups	.4726	42	.0113	
Total	.4987			

Table 2

Summary of Analysis of Variance for Terminal Level of Responding

Source	Sum of Squares	df	Mean Square	F
Between Groups	.0196	2	.0098	2.40 n.s.
Grand Mean	.0057	1	.0057	1.41 n.s.
Within Groups	.1713	42	.0041	
Total		45		

The grand mean was tested to see if it was different from log 11. The F for this test was not significant at the 5% level. For the untransformed data this means that habituation proceeds to a zero level in the last six trials.

To answer the question of whether the slopes of the group lines were significantly different from each other a regression analysis suggested by Acton (1959) was performed on the transformed data. This method tests to see if the data will best be fit by one line or three by fitting one line to the pooled data and one line to the data of each group. A statistical analysis may then be performed using the residual variances around the one line and the three lines. The results of this analysis appear in Table 3. The F test for the residual variances about a common line or three separate lines was not significant at the 5% level.

The question arises whether a significantly better fit is obtained by fitting only slope constants for each of the three groups. In this test appropriate constants are added to the scores in each group to make them have equal means and an analysis is performed on the residual variance about the three lines fitted to the adjusted data. The results of this test are included in Table 3. The F in this test was not significant at the 5% level. A comparable procedure allows a test of differences in the fitted means. This test yielded an F which was not significant at the 5% level.

The regression analyses showed that the three groups did not differ either in their slope constants or in their means. Thus, the three intensities of stimulation produced no differences either in

Table 3

Summary of Regression Analysis on the Transformed Data

Source	SS	df	MS	F
Total SS Residual About Common Line	0.1562	19		
Reduction Due to Fitting Three Lines	0.0476	4	0.0476	1.64 n.s.
Reduction for Separate Means	0.0122	2	0.0061	.... n.s.
Reduction for Separate Slopes	0.0354	2	0.0177	2.20 n.s.
Pooled SS Residual About Three Lines	0.1087	15	0.0072	
Pooled About Three Lines and Within Groups	2.4823	309	0.0080	

the rate of habituation or in the average level of response.

Separate analyses were performed for each of the groups to test whether the means for the trial blocks deviated from the fitted straight line by amounts larger than might be expected on the basis of the within group variability. In all three cases the F test led to the conclusion that they did not. This may be interpreted as showing that the straight lines provided a good fit to the data. The amounts of the initial variance removed by fitting straight lines to the data for the 92 db, 86 db, and 80 db groups were 93%, 69%, and 63%, respectively. The "coefficients of determination" or r values corresponding to these values are 0.93, 0.83, and 0.79. When the fit is perfect the r value equals 1.0 and, in general, the r's may be interpreted much as are correlation coefficients. For the line fitted to the pooled data 69% of the variance was removed with a corresponding coefficient of determination of $r = 0.83$. Finally, although the removal of such a large proportion of the variance implies a slope constant significantly different from zero, the slope constant of pooled data line was tested and yielded a t with 19 d.f. of 6.58, which is significant at the 5% level. Thus, the straight lines provided reasonably good fits to the data; correspondingly, a decay function with an asymptote of zero provides reasonably good fits to the original data.

Examination of the data for individual Ss showed that there were some Ss who showed little or no habituation while other Ss failed to show a startle response. It was decided to re-examine the data with these Ss removed. An index, the difference of the average response for the first and last two blocks of three trials divided by the average response for all trials, was computed for each S. The five Ss in each group showing the smallest index values were discarded. The same analyses were performed as were performed for the unselected data.

An analysis of variance for trial block 1 was performed on the selected data and is summarized in Table 4. The results of an F test showed no significant differences for initial level of responding.

An analysis of variance for trial blocks 5 and 6 was performed and is presented in Table 5. The results of an F test showed no significant differences for terminal level of responding.

The regression analyses are summarized in Table 6. A significant F was obtained for the slope constants. Here the data is better fit by three lines than one line. In the selected data, then, the differences in rate of habituation are significant.

Table 4

Summary of Analysis of Variance for Selected Data for Initial Level of Responding

Source	Sum of Squares	df	Mean Square	F
Between Groups	.0214	2	.0107	1.12 n.s.
Within Groups	.2332	27	.0086	
Total	.2546			

Table 5

Summary of Analysis of Variance for Selected Data for Terminal Level of Responding

Source	Sum of Squares	df	Mean Square	F
Between Groups	.0161	2	.0080	1.48 n.s.
Within Groups	.1469	27	.0054	
Total	.1630			

Table 6

Summary of Regression Analysis for the Selected Data

Source	SS	df	MS	F
Total SS About Common Line	.2972	19		
Reduction for Separate Means	.0221	2	.0110	1.66 n.s.
Reduction for Separate Slopes	.1753	2	.0876	13.17*
Pooled SSD About Three Lines	.0998	15	.0067	
Pooled About Three Lines and Within Groups	1.5438	204	.0076	

* $F_{.05}(2,204) = 3.04$

DISCUSSION

The following major results will be discussed: there were no significant differences between groups in initial or terminal level of responding and in the rate of habituation; a decay function with an asymptote of zero provided a reasonably good fit for all groups; and, after selection of Ss by an index designed to detect no change in response across trials, the differences in rate of habituation between groups was significant.

The main question that arises is the reason for the failure to detect any differences in initial level and rate of habituation. A number of indications point to large variability as the chief reason. The effect of stimulus intensity on the magnitude of the startle response is a well established one (Harris, 1943). Further, the largest group differences obtained were for the initial level. Yet this effect was not detectable.

The implication is that there are large inter-individual differences in the startle response. This implication is supported by examination of the individual records. It was found that in each group there were some Ss who show little or no startle response while there were others who show a large response even after a number of habituation trials. The large inter-individual variability, which appears to be present in this study, was also reported by Landis and Hunt (1939) as one of their major findings. It was also reported by Lehner (1941) for the startle response in the rat and in the habituation other responses in both rat and man.

The analyses of the selected data support the above notions.

Specifically, differences in rate of habituation were found after removal of Ss on the basis of an index designed to detect Ss who were making large contributions to variability, namely those Ss who gave small responses and those who gave large responses throughout the experiment. Unfortunately, detailed examination of the curves fitted for the selected and unselected data did not show that the appearance of significance was due uniquely to decreases in variability. That is, the slopes changed as well as the amount of variability.

Another potentially large source of variability was the crudeness of the measurement of the integrated muscle potentials. Unfortunately, integrating circuitry which would integrate over a short interval was not available and selected points from a kymographic recording had to be used. It is impossible to assess the magnitude of the variability contributed by the crude measure used, but one may surmise that it is quite large.

The positive findings of the present study were that there were no differences in terminal level, that the terminal level was not significantly different from zero, and that a decay function provided a good fit to the data. The terminal level results are not definitive since the design of the experiment was such that it could not detect the much larger differences present in initial responding. The finding of a terminal level of zero is more definitive and indicates complete habituation. Comparable results were found by Coombs (1938), Landis and Hunt (1939), Lehner (1941), though for other components of the startle response.

Finally, the present study provides definite evidence that a decay function is the appropriate function to describe the changes that occur in habituation. This finding has theoretical significance since decay functions are also appropriate for data on extinction of learned responses. This suggests that the same factors enter into both processes and that the issue of whether the response was originally learned or was innate is unimportant. It also suggests that the same theory may be applied to both types of data.

SUMMARY

In this experiment we investigated habituation of the startle response as a function of stimulus intensity. The response taken was EMG potentials from the forehead and the stimuli used were 80, 86, and 92 db pure tones. Forty-five Ss were randomly assigned to the three groups. Each S received twenty-one trials, randomly spaced between 35 and 55 seconds.

Differences in initial and terminal levels of responding and rate of habituation were not significant. An index for eliminating Ss who showed little or no habituation was used and an analysis performed on this selected data. The differences in rate of habituation were significantly different.

Examination of the individual records showed large inter-individual differences. It was suggested that the failure to detect differences due to the experimental variable resulted from the large inter-individual variability.

It was found that a decay function with an asymptote of zero provided a good fit to the data from each group.

The theoretical implications of the results were discussed.

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VITA

Herman Lowe was born in Worcester, Massachusetts on January 21, 1937, the son of Lillian and Morris Lowe. He graduated from Classical High School, Worcester, Massachusetts on June, 1955 and entered Springfield College, Springfield, Massachusetts in September of the same year. The following September he transferred to Boston University, College of Liberal Arts, where he received the degree of Bachelor of Arts in Psychology, June 1959.

In September, 1959, he entered the Graduate School of Lehigh University, Bethlehem, Pennsylvania. From June 1960 to June 1961 he was employed as a psychometrist at the Lehigh University Counseling and Testing Services. On January 31, 1960 he was married to Joyce Ivy Steiner. He graduated from Lehigh on June 1961 with the degree of Master of Science in Psychology.